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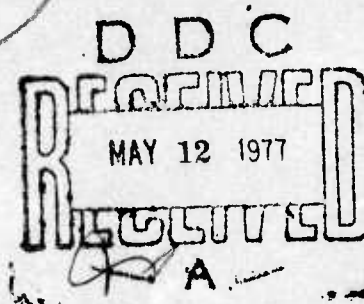
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*See 1473*



EVALUATION OF HUMIDITY INDICATORS

AFALD/PTPD  
Air Force Packaging Evaluation Agency  
Wright-Patterson AFB OH 45433

December 1976

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## ABSTRACT

Prototype humidity indicators, developed and fabricated by Foster-Miller Associates, Inc., Waltham MA under contract No. F33601-74-C-0815, were tested and evaluated by the contractor simultaneously with humidity indicators presently used or previously considered for packaging applications.

The newly developed humidity indicator is highly shock resistant, has a standard deviation of 2.2 percent RH over its calibrated range, is easily and quickly read on a calibrated scale, and is comparable in cost and mounting characteristics with the color change plug type that adapts into a 1 7/16 - 18 inch threaded hole.

From the tests conducted, some deficiencies have been identified with the newly developed humidity indicators, however, the deficiencies will be corrected prior to fabrication of preproduction prototype units.

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## INTRODUCTION

### PURPOSE:

The intent of this project was to conduct a survey among industrial manufacturers and DoD activities for an economical, self-contained, dial-type, direct read-out humidity indicator to be used as a replacement for the color change card and plug type indicators currently used by the USAF in desiccated military containers. If this type of humidity indicator was not commercially available from production, a work statement was to be written for a contractual development of a new unit.

### BACKGROUND:

Contract No. F33601-74-C-0815 was awarded to Foster-Miller Associates, Inc., 135 Second Avenue, Waltham MA 02154 to develop an improved low cost humidity indicator for packaging. The development was programmed into three tasks:

Task I covered the investigation and evaluation of commercial low-cost humidity indicators, and humidity sensing materials.

Task II required a detailed design of the humidity indicator with preliminary test data to indicate that the design will satisfy requirements of the contract statement of work.

Task III required the fabrication and testing by Foster-Miller Associates, Inc, (FMA) of ten prototype humidity indicators, delivery of 110 prototype units to the Air Force Packaging Evaluation Agency (AFPEA) for further testing and evaluation, and a cost analysis for quantity production.

## TEST AND EVALUATION

### DESCRIPTION OF TEST SPECIMENS:

Humidity indicators used for the investigation and evaluation in Task I were selected for testing because they are presently used, or have been previously considered for packaging applications. The indicators cover the following range of sensing elements and readout types:

<u>SPECIMEN</u>	<u>SENSING ELEMENT</u>	<u>READOUT TYPE</u>
No. 1	Hygroscopic Salt	Color Change
No. 2	Hygroscopic Salt	Color Change
No. 3	Hygroscopic Salt	Color Change
No. 4	Foil-Fiber Element	Pointer & Scale
No. 5	Biplastic Element	Pointer & Scale
No. 6	Human Hair	Pointer & Scale
No. 7	Nylon Cord	Pointer & Scale

#### TEST PROCEDURES AND RESULTS

Indicator Accuracy Test: The initial accuracy test of the commercial humidity indicators was conducted by mounting the test specimens, one each, on a plexiglass panel which was supported in a vertical position by bracing and was placed in a Tenney, TH-27, environmental chamber. The commercial indicators were tested to determine their performance and accuracy over a 25-90 percent RH range at temperatures from +35°F to +120°F. The humidity and temperature inside the chamber, at any test condition, was monitored with a calibrated electronic humidity indicator accurate to  $\pm 1$  percent RH (reference Table I). The probe of this indicator was mounted centrally on the test panel. In addition to a periodic visual readout, a chart recorder was connected to the calibrated instrument to monitor continuously the humidity within the chamber.

To evaluate the performance and accuracy of the commercial humidity indicators the environmental chamber was set at the required dry bulb temperature, the wet bulb temperature was then adjusted to give the required RH level. A preliminary run indicated that one-half hour was sufficient to allow all of the indicators to stabilize. Therefore, the readings at each test condition were taken one-half hour after the chamber adjustments were made.

Further tests were also carried out by mounting the test specimens, six each, in a metal 3' x 3' x 3' exterior shipping/storage container and monitoring the indicator readings for various values of container humidity, ranging from 30 percent to 60 percent RH. As with the initial tests, the temperature and humidity inside the container was also monitored with the calibrated electronic humidity indicator.

Tests were also conducted on the prototype humidity indicators developed by Foster-Miller Associates, Inc. All testing was performed in the same sequence as the tests made on the commercially procured humidity indicators. However, four (4) hours, as opposed to one-half hour for the commercial humidity indicators, were required for the new prototype humidity indicators to stabilize.

Results:

<u>Indicator</u>	<u>Standard Deviation % RH</u>
Hygroscopic Salt	8.0 (Average)
Foil-Fiber Element	10.8
Biplastic Element	10.3
Human Hair	6.2
Nylon Cord	1.9
FMA Prototype	2.2

Based on the results obtained from the initial performance tests, the following humidity indicators were selected for future test and evaluation: Specimen No. 1, Plug Type (Figure 1), Specimen No. 7, Nylon Cord Sensing Element (Figure 2), and the Foster-Miller Associates, Inc., Waltham MA, Prototype Unit (Figure 3).

Stability Test: Long term stability was evaluated by comparing the test data taken at the beginning of the program with that which was obtained at the end of an 18 month period using the same test specimens.

Results: At the end of 18 months the color change indicators showed no detectable difference. The nylon cord hygrometer had an average increase of 13 percent RH in the 30-70 percent RH range. The error was larger at the lower humidities. At the end of 30 days the FMA prototype indicators showed a variation of approximately one percent RH from the standard. Although this is not comparable to an 18 month test, it was felt that the units required a slight refinement to improve their stability. The FMA prototype units were modified, a 30-day stability test was then repeated and no reading variations were observed.

Rough Handling Test: Rough handling tests were conducted in accordance with Federal Test Method Standard No. 101, Methods 5005 and 5008, level A protection, using a drop height of 30 inches. The humidity indicators were mounted in exterior containers and two drops were made on each of the six units that were tested.

Results: As expected, the color change indicators showed no difference in readings after the rough handling tests were completed. The FMA prototypes also showed no change in readings. The nylon-cord hygrometers showed a significant shock-induced change. One unit became inoperative while the others showed an error increase of five percent RH.

Resolution Test: To test resolution, reading ease and accuracy, observations were made by various observers by reading the units from different distances and under different light conditions.

Results: The results for reading accuracy indicated that observers can estimate within 10 percent RH the color change indicators. By contrast, readings of both the nylon-cord hygrometer and FMA prototypes were less than one percent RH.

Response Time Test: Response time of the humidity indicators was evaluated by monitoring the readings of the indicators after a sudden drop in humidity. This was accomplished by initially conditioning the test indicators in a sealed container for 24 hours at 45 percent RH. The container was then opened and the indicators were exposed to an ambient humidity level of 30 percent RH. Readings were taken at five minute intervals until the 30 percent RH level was recorded for each indicator.

Results:

<u>Indicator Type</u>	<u>Response Time</u>
Color Change Plug	15-30 Minutes
Nylon-Cord Hygrometer	15 Minutes
FMA Prototype	4 Hours

Pressurized Container Test: Pressure testing of humidity indicators was accomplished by mounting the indicators in an exterior container, which was sealed and pressurized with air to five psi. This test was conducted to determine: (1) indicator fluid leakage, (2) seal leakage, and (3) reading error caused by the internal pressure.

Results: None of the indicators showed any air leakage through the seals, and no change was observed in any of the readings.

Temperature Compensation Test: Temperature compensation tests were performed by mounting the indicators in exterior containers and exposing the containers to ambient indoor and outdoor conditions and also to

temperature extremes within an environmental chamber. The test temperature of the environmental chamber ranged from +40°F to +110°F. The temperature and humidity were monitored with the calibrated instrument of Table I.

Results:

<u>Indicator Type</u>	<u>Deviation</u>
Color Change	5 percent RH per 10°F
Nylon Cord Hygrometer	1/2 percent RH per 10°F
FMA Prototype	2/3 percent RH per 10°F

Mounting Characteristic Test: Humidity indicators were mounted in exterior containers to study the advantages and disadvantages of the mounting characteristics.

Results: The color change plug and the FMA prototype indicators have an identical mounting arrangement. These indicators can be mounted from the outside of the container into a threaded hole or can be fastened by means of a backup nut. The nylon cord hygrometer must be mounted from the inside of the container and must be locked in place by means of a nut from the outside. For large containers where the mounting location is not easily accessible from the inside, this mounting arrangement is inconvenient. Also, the protective cover for the scale and pointer must be removed, thus exposing the delicate parts to accidental impact, when the indicator is being mounted.

CONCLUSION

The survey conducted among industrial manufacturers and DOD activities revealed a nonavailability of a replacement of an economical, self-contained and direct readout type of humidity indicator for USAF use.

The performance of the FMA prototype unit indicates the following advantages:

- a. The standard of deviation for the FMA prototype humidity indicator, at 2.2 percent RH over its calibrated range, was slightly higher than the 1.9 percent RH for the nylon cord hygrometer. However, at 2.2 percent RH it is within the range as specified in the Statement of Work.

b. When mounted and tested in exterior shipping/storage containers the nylon cord hygrometer failed during the stability and rough handling tests. The FMA prototype has no moving links or pivots, has ten component parts compared to forty-five parts on the nylon cord hygrometer, resulting in a design that is highly shock resistant.

c. Graduated scale is read easier, quicker, and more accurately than the color change type.

d. Response time, pressurization, and temperature compensation were within the range as specified in the Statement of Work.

e. Mounting characteristics are compatible with the present system used within the USAF distribution system.

f. Production cost computed at \$6.62 for each unit (1975 prices) is comparable to the plug type presently used in the USAF distribution system and approximately four times less than the cost of the nylon cord hygrometer.

The following are disadvantages noted in the FMA prototype humidity indicator:

a. Sensing unit is exposed to accidental impact.

b. Requirement exists for percent RH read-out below the 30-70 scale calibration.

c. Although pressure tests of five psi are within the Statement of Work unit cannot survive shipment in unpressurized aircraft.

#### RECOMMENDATIONS

As a result of work conducted thus far, it is recommended that:

a. Some additional features be incorporated in the present design of the humidity indicators including:

(1) Protect unit against mishandling by inclusion of guard disc over the sensing unit.

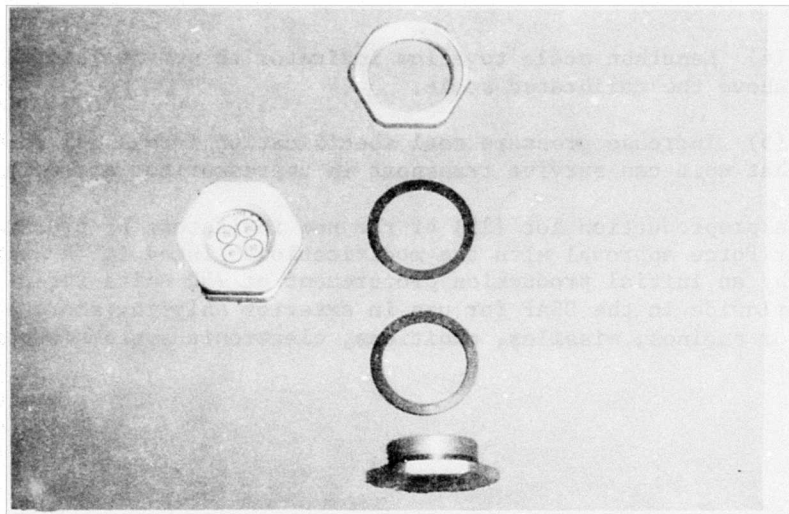
(2) Change scale calibration from 30-70 percent RH to 20-60 percent RH.

(3) Standard of deviation over the calibrated scale of 20-60 shall be 2.0 percent RH.

(4) Lengthen scale to allow indicator to survive humidity exposure above the calibrated scale.

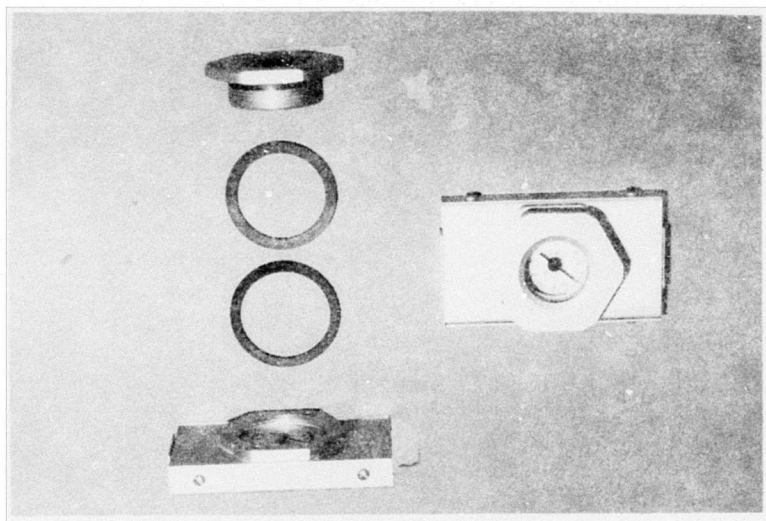
(5) Increase pressure seal specification from 4 psi to 19 psi, so that unit can survive transport in unpressurized aircraft.

b. A preproduction lot (25) of the new indicators be procured for US Air Force approval with the modifications listed in "a" above, followed by an initial production procurement of 750 units for distribution worldwide in the USAF for use in exterior shipping/storage containers for engines, missiles, munitions, electronic systems/components, etc.



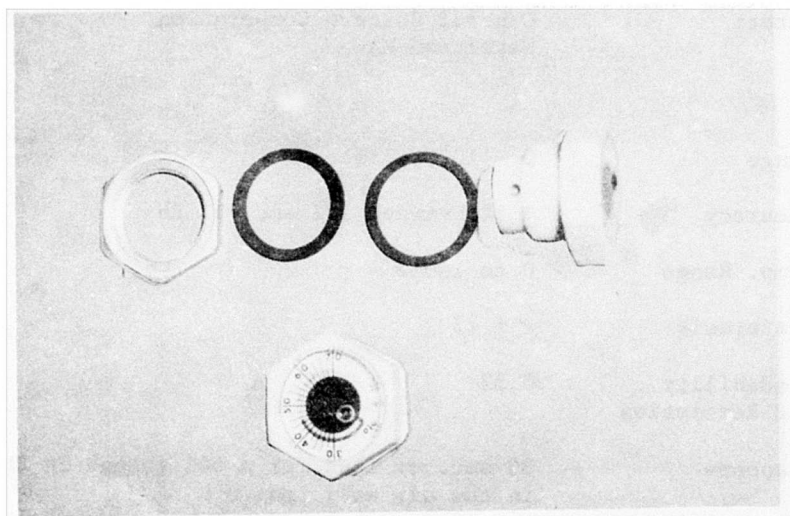
SPECIMEN NO. 1 - PLUG TYPE

FIGURE 1



SPECIMEN NO. 7 - NYLON CORD SENSING ELEMENT

FIGURE 2



FOSTER-MILLER ASSOCIATES, INC. - PROTOTYPE UNIT

FIGURE 3

TABLE I

REFERENCE INDICATOR SPECIFICATIONS

Indicator:	Model 400C, Temperature Compensated Analog Indicator
Probe:	Model 411, RH and Temperature Sensor
Manufacturer:	General Eastern Corporation Watertown MA

Humidity

Range	0 - 100%, linear
Accuracy	$\pm 1\%$ between 15% and 95% RH
Temp. Range	0 to 140°F
Hysteresis	$< \pm 2\%$
Readability and Resolution	0.5%
Response	30 sec. or less for a 64% change in RH in the air at 1 fps.

Temperature

Range	- 50 to + 150°F
Accuracy	$\pm 2^\circ\text{F}$
Readability	0.5°F

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#20. ABSTRACT (Cont'd)

The newly developed humidity indicator is highly shock resistant, has a standard deviation of 2.2 percent RH over its calibrated range, is easily and quickly read on a calibrated scale, and is comparable in cost and mounting characteristics with the color change plug type that adapts into a 1 7/16 - 18 inch threaded hole.

From the tests conducted, some deficiencies have been identified with the newly developed humidity indicators, however, the deficiencies will be corrected prior to fabrication of preproduction prototype units.

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